PHOTOMASK FOR NEAR-FIELD EXPOSURE, NEAR-FIELD EXPOSURE METHOD, AND NEAR-FIELD EXPOSURE APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a photomask for near-field exposure, a near-field exposure method, and a near-field exposure apparatus with which a minute pattern can be formed.

Related Background Art

As semiconductor memories are increased in capacity and CPU processors are enhanced in processing speed and level of integration, further miniaturization of photolithography is becoming indispensable. In general, photolithography apparatus's ability of fine processing is limited by the wavelength of light the apparatus uses.

With the trend being that light of shorter wavelength is used in photolithography apparatuses, ultraviolet lasers are now employed allowing fine processing on the order of 0.1 μm.

After all this advancement in miniaturization, photolithography still has many problems to clear up in order to achieve fine processing of 0.1 μm or finer, for instance, further shortening of laser wavelength and development of a lens that works for that shorter wavelength range.

There has been proposed, as a measure for allowing optical fine processing of 0.1 μm or finer, a fine processing apparatus that uses the structure of a scanning near-field optical microscope (hereinafter abbreviated as SNOM). For example, the apparatus uses evanescent light that seeps from a micro aperture with a size of 100 nm or less to perform on resist local exposure that surpasses the limit of the wavelength of light.

However, any lithography apparatus that has the SNOM structure uses one (or more than one) processing probe to carry out fine processing unicursally, which has the problem that high throughput cannot be achieved.

USP 6,171,730 B1 (Japanese Patent Application Laid-Open No. H11-145051) discloses a method to solve this problem. According to the proposed method, a patterned photomask to let near-field light seep through a gap between shielding membranes is brought into close contact with a photoresist on a substrate and then the photoresist is exposed to light, thereby transferring the minute pattern of the photomask onto the photoresist at once. The disclosed method is an excellent method and is of a great contribution to the technical field to which the present invention belongs.

The above-described near-field exposure method

is capable of manufacturing a minute pattern of about several tens nm, which is far smaller than the wavelength of exposure light. Accordingly, the above specification proposes to form a membrane portion in a photomask and to use pressure to let the membrane portion sag and to approach a photoresist to the near-field exposure region before the photoresist is exposed to light.

A description is given on light exposure that uses a photomask structured as shown in Figs. 11A and 11B. In Fig. 11A, the photomask has a membrane portion 104, which is composed of a shielding membrane 102 and a membrane parent material 103. The shielding membrane 102 has a light exposure pattern 101.

In order to take full advantage of near-field exposure capable of manufacturing a minute structure beyond the limit of diffraction of light, it is necessary that the light exposure pattern 101 and a photoresist 107 approach each other to be in a near-field region (the distance between the two should be 100 nm or less, although it varies depending on the size of the light exposure pattern) during exposure. The membrane portion 104 is therefore sagged upon exposure so that the light exposure pattern is closely fitted to the photoresist (Fig. 11B).

The membrane portion that is brought into close

contact with the resist is peeled off of the resist after exposure is completed. Under certain conditions, the membrane portion could be broken through repetitive fitting and peeling, thus making the photomask useless. When the membrane portion is torn, it mostly takes place at a border portion 106, which is the border between the membrane portion 104 and a substrate 105. This is probably because the stress caused by sagging of the membrane portion 104 locally concentrates on the border portion 106 between the substrate 105 and the membrane portion 104.

Fig. 10 shows a simulation of how the stress caused by sagging of the mask works on the membrane portion. In Fig. 10, the axis of abscissa indicates the distance from the center of the membrane portion and the axis of ordinate indicates tensile stress generated in the membrane portion. The membrane portion is 10 mm in diameter and the calculations are made accordingly.

As is clear from Fig. 10 and Figs. 11A and 11B, the force applied to the membrane portion concentrates on the border portion 106 shown in Figs. 11A and 11B, and the magnitude, as well as degree of concentration, of the force applied to the membrane portion is increased as the area where the photomask is in close contact with the photoresist is expanded.

This means that the more the contact area is expanded to increase the light exposure pattern in size, the less durable the membrane portion becomes.

The magnitude of the force applied to the membrane portion is also dependent on the distance between the resist and the mask before the mask is sagged, and a larger force is applied to the membrane portion as the mask-resist distance is increased. In order to reduce the force applied to the membrane portion and improve the durability of the photomask, the mask-resist distance should be set small. A fine, vertically-movable stage is necessary to control a small distance with precision. For instance, when exposing a photoresist to light by the step-and-repeat method in a stepper exposure apparatus, the position of the photoresist relative to a photomask is changed in a short period of time during exposure and it is therefore undesirable to raise the positional precision excessively since it takes time. In addition, this makes the stage costly. As has been described, it is difficult to raise the precision of the mask-resist distance, in other words, to reduce the distance between the resist and the mask before the mask is sagged.

SUMMARY OF THE INVENTION

The present invention has been made in view of

the above, and an object of the present invention is therefore to provide a photomask for near-field exposure which has a membrane portion and which is hard to break and is durable even when used for exposure of a large area to light.

Another object of the present invention is to provide a photomask for near-field exposure whose membrane portion is durable even when the mask-resist distance is large.

A photomask for near-field exposure according to the present invention includes the following aspects.

(1) A photomask for near-field exposure, including:

a substrate; and

a membrane portion supported by the substrate and having on one side of the membrane portion a shielding membrane that has a micro aperture,

in which the photomask has such a structure as to relieve stress that is generated in the border between the membrane portion and the substrate when the membrane portion is sagged.

(2) A photomask for near-field exposure according to aspect (1), in which the structure disperses, over the membrane portion, deformation of the membrane portion at the border between the membrane portion and the substrate.

(3) A photomask for near-field exposure according to aspect (2), in which the structure has a thick part in a region of the membrane portion that abuts the border between the membrane portion and the substrate.

(4) A photomask for near-field exposure according to aspect (3), in which the structure is such that the thickness of the membrane portion is increased toward the border between the membrane portion and the substrate.

(5) A photomask for near-field exposure according to aspect (1), in which the structure is such that the thickness of the shielding membrane around the membrane portion is larger than that in the center portion of the membrane portion.

(6) A photomask for near-field exposure according to aspect (1), in which the structure is composed of a reinforcing member placed at the border between the membrane portion and the substrate.

(7) A photomask for near-field exposure according to item (1), in which the structure is composed of another layer provided on the shielding membrane around the membrane portion.

(8) A photomask for near-field exposure according to aspect (2), in which the structure is an intermediate layer that is formed between the substrate and the membrane portion and stretches

toward the membrane portion side.

(9) A photomask for near-field exposure according to aspect (1), in which the structure disperses, over the substrate, deformation of the membrane portion at the border between the membrane portion and the substrate.

(10) A photomask for near-field exposure according to aspect (9), in which the structure is such that the thickness of the substrate is decreased toward the border between the membrane portion and the substrate.

(11) A photomask for near-field exposure according to aspect (1), in which the structure splits vertical displacement caused by sagging of the membrane portion between at least two locations.

(12) A photomask for near-field exposure according to aspect (11), in which the structure is a deformable concave portion or a hole structure that is formed in a region around the membrane portion and /or in the substrate.

(13) A photomask for near-field exposure according to aspect (12), in which the concave portion is filled with a material other than that of the substrate.

(14) A photomask for near-field exposure according to aspect (11), in which the structure is a movable portion that is formed outside the substrate

along the border between the membrane portion and the substrate.

(15) A photomask for near-field exposure according to aspect (14), in which, when the membrane portion is sagged, the movable portion changes the position of the substrate to cause vertical displacement of the membrane portion.

(16) A photomask for near-field exposure according to aspect (15), in which the vertical displacement of the membrane portion which is caused by the movable portion is larger than the sagging amount of the membrane portion.

(17) A photomask for near-field exposure according to aspect (14), in which the movable portion is an elastic hinge structure.

(18) A photomask for near-field exposure according to aspect (14), in which the movable portion is a blade spring.

A photomask according to the present invention includes a stress relieving structure. The stress relieving structure relieves stress concentrating locally on the border between the membrane portion and a substrate, and thus the durability of the photomask can be improved.

Further, according to the present invention, there is provided a near-field exposure method for exposing a object to be exposed to light including:

fitting a shielding membrane of a photomask for near-field exposure to the object; and irradiating the object with light from a light source through the shielding membrane, the photomask being composed of a substrate and a membrane portion that is supported by the substrate and has on one side of the membrane portion the shielding membrane, the shielding membrane having a micro aperture,

in which the photomask has a structure for relieving stress that is generated in the border between the membrane portion and the substrate when the membrane portion is sagged.

In addition, according to the present invention, there is provided a near-field exposure apparatus including:

a light source;

a stage on which a object to be exposed to light is placed; and

a photomask composed of a substrate and a membrane portion, the membrane portion being supported by the substrate and having on one side of the membrane portion a shielding membrane that has a micro aperture,

in which the shielding membrane is brought into close contact with the object placed on the stage so that the object is irradiated with light from the light source through the shielding membrane for

exposure; and

the photomask has a structure for relieving stress that is generated in the border between the membrane portion and the substrate when the membrane portion is sagged.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1A and 1B are diagrams showing a structure of a photomask according to Embodiment 1;

Figs. 2A, 2B, 2C, 2D, 2E and 2F are diagrams showing a process of manufacturing a photomask according to Embodiment 1;

Figs. 3A, 3B, 3C and 3D are diagrams showing structures of photomasks according to Embodiments 2 and 3;

Figs. 4A and 4B are diagrams showing a structure and operation of a photomask according to Embodiment 4;

Figs. 5A, 5B, 5C, 5D, 5E and 5F are diagrams showing a process of manufacturing a photomask according to Embodiment 4;

Figs. 6A, 6B and 6C are diagrams showing structures of photomasks according to Embodiments 5 and 6;

Figs. 7A, 7B and 7C are diagrams showing a structure and operation of a photomask according to Embodiment 7;

Figs. 8A, 8B and 8C are diagrams showing the structure of the photomask according to Embodiment 7;

Figs. 9A and 9B are diagrams showing the structure of the photomask according to Embodiment 7;

Fig. 10 is a diagram showing results of simulating stress applied to a membrane portion; and

Figs. 11A and 11B are diagrams showing the structure of a conventional photomask.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

According to the present invention, a mask is provided with a structure that prevents stress from concentrating on a narrow border portion between a membrane portion and a substrate and relieves the stress when the membrane portion is sagged and deformed in the process of bringing the mask in close contact with a resist. The stress concentration relieving structure can provide at least one of the following effects:

One effect is to expand a region to which the stress is applied and thereby to disperse the stress. In the conventional structure, the membrane portion is allowed to deform until it reaches the very border of the substrate while the shape of the substrate remains unchanged. This causes the deformation of the membrane portion to concentrate on the border portion 106 (Fig. 11B) of the membrane portion,

concentrating the stress in the narrow region. By dispersing and relieving the deformation of the membrane portion, the region to which the stress is applied is expanded and the distortion energy per unit area is reduced. As a result, the durability of the mask is improved.

The deformation, or the stress, can be dispersed by making the deformation or stress disperse over the membrane portion, or over the substrate, instead of the border between the substrate and the membrane portion.

Another effect is to split the stress by dividing a region to which the stress is applied into two or more. When the stress concentrates on a narrow region, the border portion 106 (Fig. 11B) of the membrane portion is sharply deformed. With the stress applied to plural regions, the membrane portion is deformed step by step and the stress level of each region is lowered. The stress concentrated on a narrow region is thus split to improve the durability of the mask.

Specifically, the substrate is provided with a movable portion and displacement of the movable portion partially substitutes for sagging deformation of the mask. The movable portion allows the substrate to change its position in a direction perpendicular to the surface of the membrane portion,

so that the membrane portion fixed to the substrate is shifted vertically. In this way, the membrane portion is less sagged in order to bring the mask in close contact with the resist and the stress is thus relieved.

This structure makes it possible to set large the distance between a mask and a resist before the mask is sagged, thereby enhancing the durability of the mask as well as decreasing the level of the machine precision required to control the mask-resist distance, thereby improving the throughput. In addition, the structure makes it possible to expose a large-area to light.

The present invention will be described below through more specific examples.

Embodiment 1

A first stress dispersing structure of the present invention is shown in Fig. 1A. Fig. 1A illustrates a photomask for near-field exposure in which a reinforcing member constituting the stress dispersing structure is formed around a membrane portion.

A method of manufacturing this photomask will be described below with reference to Figs. 2A to 2F.

(1) A membrane parent material 201 is formed into a film on each side of a photomask substrate 105 (Fig. 2A).

(2) The membrane parent material 201 on one side of the substrate 105 is positioned and patterned so that the parent material serves as an etching mask for forming a membrane portion (Fig. 2B).

(3) A shielding membrane 202 is formed on the membrane parent material 201 that is not patterned on the other side (Fig. 2C).

(4) A portion of the shielding membrane 202 that has no level difference is processed to form a light exposure pattern 101, which is a fine pattern or the like used to expose a resist to light (Fig. 2D).

(5) The membrane parent material patterned in Fig. 2B is used to etch the substrate 105 and thereby to form a membrane portion 104 (Fig. 2E).

Although the step of forming the membrane portion 104 by etching the substrate 105 is the last step in the above description, this is not fixed and the membrane portion 104 may be formed before forming the shielding membrane, or after the shielding membrane is formed and before the level difference structure is formed.

(6) Lastly, a reinforcing member 108 that is a stress relieving structure is formed around the membrane portion.

The material and thickness of the reinforcing member are adjusted such that a border portion 106 is

deformed gently, instead of sharply, as shown in Fig. 1B when the membrane portion 104 is sagged in the process of exposure. For example, the reinforcing member 108 is formed only around the membrane portion from a high viscosity polymer or gel using a spin coater or an evaporator. Another example is to form the reinforcing member 108 only around the membrane portion (on the membrane parent material including the vicinity of the substrate) by oblique evaporation.

The membrane portion 104 of the thus obtained photomask for near-field exposure is sagged to bring the photomask to come in close contact with a photoresist 107. Compared to the sharp deformation of the border portion 106 in Fig. 11B, a part of the membrane portion 104 that abuts the border of the substrate is supported by the stress relieving structure 108 and is deformed gently as shown in Fig. 1B. The stress applied to the membrane portion is dispersed over a stress relieving portion 109 inside (the membrane portion side) the border and accordingly the durability of the photomask is improved.

Embodiment 2

A second stress dispersing structure of the present invention is shown in Fig. 3A. Fig. 3A illustrates a photomask for near-field exposure in which a stress dispersing structure is formed by

varying the thickness of a substrate around a membrane portion. The substrate is thinned near the border between the substrate and the membrane portion.

The structure in Fig. 3A can be manufactured by an approximately the same method as the one illustrated in Figs. 2A to 2F. The difference is that, in this case, Fig. 2E is replaced by two-step dry etching for etching the substrate and forming the membrane portion. A level difference in the substrate can be adjusted by controlling the depth for dry etching in the first step. A level difference region of the substrate can be adjusted by controlling the area to be dry-etched in the first and second steps.

By adjusting the substrate level difference and the substrate level difference region, the degree of relief of stress concentration is adjusted.

When the membrane portion is sagged, the substrate, which is formed thin around the membrane portion, is caused to sag along with the membrane portion. A mask parent material portion is supported by a level difference in the substrate, in other words, the stress is dispersed over a thin stress relieving portion 301 on the substrate side in this embodiment instead of the border between the membrane portion and the substrate. Therefore, sharp deformation of the membrane portion is relieved and

the durability of the photomask is improved.

In this embodiment, the substrate level difference region serving as a stress relieving structure is integrated with the substrate. Accordingly, this embodiment is capable of avoiding risks of lowering the exposure accuracy and breaking the mask which are due to misalignment caused by repeatedly sagging the photomask to change the stress relieving structure.

An example of modifying the stress dispersing structure of this embodiment is shown in Fig. 3B. Fig. 3B illustrates a photomask in which a stress dispersing structure is formed by varying the thickness of a substrate around a membrane portion in a continuous manner.

The structure in Fig. 3B can be manufactured by the approximately same method as the one illustrated in Figs. 2A to 2F. The difference is that, in this modification example, Fig. 2E is replaced by isotropic etching for etching the substrate and forming the membrane portion. When Si is used for the substrate, a mixture of hydrofluoric acid, nitric acid, and acetic acid, for example, is used as an etchant for wet etching to obtain the structure of Fig. 3B. The radius of curvature of the etching is adjusted by adjusting the mixing ratio of the above three acids in the etchant.

When the membrane portion is sagged, the substrate 105 around the membrane portion is caused to sag gently since the substrate 105 is thinned toward the membrane portion. A membrane parent material 103, which is formed around the membrane portion and is supported by the substrate, is also sagged gently. The stress is dispersed more over a stress relieving portion 301 as in Embodiment 2, thus relieving sharp deformation of the membrane portion. As a result, the durability of the photomask is improved even more.

Also in this embodiment, the substrate level difference region serving as a stress relieving structure is integrated with the substrate. Accordingly, this embodiment is capable of avoiding risks of lowering the exposure accuracy and breaking the mask which are due to misalignment caused by repeatedly sagging the photomask to change the stress relieving structure.

In addition, the membrane portion 104 and the stress relieving structure are formed at once by wet etching, thus reducing the number of steps for manufacturing a mask and improving the throughput of mask manufacture.

Embodiment 3

While a stress relieving structure is formed by varying the thickness of a photomask substrate in

Embodiment 2, a third stress dispersing structure of this embodiment is obtained by increasing the thickness of a membrane portion near the border between the membrane portion and a substrate.

In a structure of Fig. 3C, the thickness of a membrane parent material 302 is increased only around a membrane portion.

In a structure of Fig. 3D, an intermediate layer 303 is provided between a membrane portion and a substrate to support the region around the membrane portion in a stepped manner. With either of the stress relieving structures, a thick part of the membrane portion that is inside (the membrane portion side) the border between the membrane portion and the substrate serves as a stress relieving portion 301, and deformation is dispersed over the region 301. Thus sharp deformation of the membrane portion is relieved and the stress is dispersed. The photomask durability is therefore improved.

Embodiment 4

The thick part of the membrane portion (the thick portion of the membrane parent material 302 or the intermediate layer 303), which is on the side opposite to the shielding membrane in Embodiment 3, may be formed on the shielding membrane side. This photomask structure is a fourth stress dispersing structure of the present invention, and is shown in

Fig. 4A. In the structure of Fig. 4A, a level difference structure 401 is provided on the shielding membrane side of a membrane portion and the thickness of the membrane portion is increased near the border between the membrane portion and a substrate.

A process of manufacturing the photomask according to Embodiment 4 will be described below with reference to Figs. 5A to 5F.

(1) First, a membrane parent material 201 is formed into a film on each side of a photomask substrate 105 (Fig. 5A).

(2) The membrane parent material 201 on one side of the substrate 105 is positioned and patterned so that the parent material serves as an etching mask for forming a membrane portion (Fig. 5B).

(3) A shielding membrane 202 is formed on the membrane parent material 201 that is not patterned on the other side (Fig. 5C).

(4) A film to form the level difference structure 401 is formed on the shielding membrane 202. The level difference structure can be formed from any material as long as it can create a level difference from the shielding membrane and it is readily peeled off of a resist. However, the use of metal for the level difference structure makes the process easy. Examples of employable metal include Cr, Ag, Au, Ta, and Al. A resist is applied to the level difference

structure 401 followed by light exposure by a normal exposure apparatus and development to obtain a resist structure, which extends inward beyond a membrane portion 104. The level difference structure 401 is formed by evaporating and depositing the material of the level difference structure and then removing the resist (Fig. 5D).

(5) A portion of the shielding membrane 202 that has no level difference is processed to form a light exposure pattern 101, which is a fine pattern or the like used to expose a resist to light (Fig. 5E).

(6) The membrane parent material patterned in Fig. 5B is used to etch the substrate 105 and thereby to form a membrane portion 104 (Fig. 5F).

Although the step of forming the membrane portion 104 by etching the substrate 105 is the last step in the above, this is not fixed and the membrane portion 104 may be formed before forming the shielding membrane, or after the shielding membrane is formed and before the level difference structure is formed.

The membrane portion 104 of the photomask is sagged to decrease the distance between the light exposure pattern 101 and a photoresist 107 for exposure (Fig. 4B). Then the level difference structure 401 causes the membrane portion to deform

in two stages and the stress that has concentrate on a border portion 106 is dispersed over a stress relieving portion 402.

The stress relieving structure in which a level difference is formed in the shielding membrane to relieve concentration of the stress brought by the sagged membrane portion improves the durability of the photomask.

A metal film separate from the shielding film is used to form the level difference structure 401 in the above example. Alternatively, the level difference structure 401 may be formed by varying the thickness of the shielding membrane 102 in such a manner that the thickness of the shielding film varies to achieve the structure of Figs. 4A and 4B. This structure can be obtained by forming the shielding membrane with two stages. With the shielding membrane 102 and the level difference structure 401 unitarily formed, it is possible to avoid a risk of peeling-off caused between the shielding membrane 102 the level difference structure 401 when fitting and peeling of the photomask is repeated.

Embodiment 5

A first stress splitting structure of the present invention is shown in Fig. 6A. Fig. 6A illustrates a photomask for near-field exposure in

which a stress relieving membrane portion is formed as a stress splitting structure outside a substrate that surrounds a membrane portion.

The structure in Fig. 6A can be manufactured by almost the same method as the one illustrated in Figs. 2A to 2F. A mask pattern is formed such that a stress relieving membrane portion is formed around a membrane portion when manufacturing the mask for forming the membrane portion of Fig. 2B. The etching in Fig. 2E completes the structure of Fig. 6A.

The stress relieving membrane portion surrounds the periphery of the substrate around the membrane portion 104, which is in close contact with the surface to be exposed to light. When the light exposure pattern is brought into close contact with a photoresist in the exposure process, the stress relieving membrane portion and the membrane portion that has the light exposure pattern are separately sagged. As a result, the stress is split. With the stress split, sharp deformation of the membrane portion is relieved and the photomask is improved in durability.

In addition, since the stress relieving membrane portion can be formed at the same time of forming the membrane portion 104 having the light exposure pattern, the throughput in manufacturing a mask is improved.

(Modification Example 1)

As shown in Fig. 6B, a hole created in the surrounding substrate 105 in order to form a stress splitting membrane portion may be filled with other material than the substrate 105.

The structure in Fig. 6B can be manufactured by almost the same method as the one used to fabricate the structure of Fig. 6A. A hole created around the membrane portion may be filled after the structure of Fig. 6A is completed. However, in order to avoid a risk of breaking the membrane portion by impact applied in handling, it is preferable to set etching of the membrane portion as a last step in which a hole in the substrate 105 around the membrane portion is created first by etching. The hole is filled with a material having a Young's modulus smaller than that of the substrate 105.

The material having a Young's modulus smaller than that of the substrate 105 includes an organic material such as resist, a high viscosity polymer or gel, and metal. The material is, for example, poured or deposited by evaporation to fill the hole.

Obtained by filling the hole is a filling structure 304, the material and thickness of which is adjusted to have an elastic constant lower than that of the substrate 105.

With the filling structure 304 provided around

the membrane portion, the stress is split between the filling structure 304 and the membrane portion having the light exposure pattern when the light exposure pattern is brought into close contact with the photoresist in the exposure process. Since the stress is split, sharp deformation of the membrane portion is relieved and the photomask is improved in durability.

(Modification Example 2)

The filling structure 304 may be placed in a region around the membrane portion 104 where the light exposure pattern 101 is not formed (Fig. 6C). In this case, a filling material that is low in transmittance of exposure light is employed. If a filling material that is transmissive of exposure light is employed, the hole is formed in a location where the light exposure pattern does not affect the performance of the device to be manufactured.

In this case, the hole may not be filled if gas leakage does not significantly interfere with control of pressure for sagging the membrane portion.

With this structure, the membrane portion is deformed in a border portion 106 and in a stress relieving portion 301 separately. The stress is thus split, relieving sharp deformation of the membrane portion and improving the durability of the photomask.

Embodiment 6

A second stress splitting structure of the present invention is shown in Fig. 7A. Fig. 7A illustrates an example in which a movable portion is formed as a stress splitting structure around a substrate 105 of a photomask. The movable portion may be an elastic body, a mechanical movable mechanism, an electric movable mechanism, or the like. Here, an elastic hinge structure 601 is formed around a mask substrate by utilizing a micromachining process. The movable portion is supported by a substrate 604, which is outside of the elastic hinge structure 601.

The elastic hinge structure 601 is elastically deformed due to a difference in atmospheric pressure or upon application of fluid pressure, electrostatic force, electromagnetic force, or the like, thereby causing the substrate to change its position in a direction perpendicular to the surface to be exposed to light. It is also possible to deform the elastic hinge structure by creating an atmospheric pressure difference between above and below the structure.

Using this photomask, a photoresist is exposed to light as follows:

The elastic hinge structure 601 is deformed to bring the membrane portion 104 together with the substrate close to the surface to be exposed to light (Fig. 7B). The membrane portion 104 is further

sagged utilizing a pressure difference or the like (Fig. 7C). Then a light exposure pattern 101 is fit to an object to be exposed to light (photoresist 107) which is placed on a stage (not shown in the drawings). The object to be exposed to light (photoresist 107) is irradiated with light from a light source (not shown in the drawings) for exposure through a membrane parent material 103 and a shielding membrane 102.

After the exposure, the pressure difference or the like is returned to the initial setting (or set to the opposite value) to undo the sagging of the membrane portion 104. Then the elastic hinge structure 601 is driven to return to the initial state (Fig. 7A).

Alternatively, the membrane portion may be sagged by creating a difference in atmospheric pressure on each side of the mask while at the same time the identical atmospheric pressure difference is given to the elastic hinge structure to deform the structure.

The deformation of the elastic hinge structure 601 causes the substrate to move down in the vertical direction and, accordingly, the membrane portion similarly moves down. The movement closes the distance between the membrane portion and the surface to be exposed to light which are largely apart from

each other before the deformation. Therefore, compared to a case where no elastic hinge structure is provided, a less amount of sagging of the membrane portion is required in order to fit to the surface to be exposed to light.

The above-described exposure method using a photomask of the present invention is also applicable for the photomasks of other embodiments and modification examples.

The mask-resist distance, which is large before the deformation (Fig. 7A), is changed to be smaller by deforming the movable portion and thus moving the membrane portion along with the substrate as shown in Fig. 7B. How far the membrane portion is moved is indicated by d1 in Fig. 7C. As a result of the movement, the mask-resist distance is reduced to d2 in Fig. 7C. Since the membrane portion has to be sagged only by d2, the stress is relieved more than when no movable portion is provided.

The sagging amount of the membrane portion 104 is reduced by a stress relieving portion 602 and therefore the stress applied to a border portion 603 of the membrane portion can be reduced. The stress, which concentrates on the border portion 106 in Figs. 11A and 11B, is split between the stress relieving portion 602 and the border portion 603 in Figs. 7A to 7C. The photomask is thus improved in durability.

The outer substrate 604 connected to the membrane portion 104 through the elastic hinge structure 601 is fixed to a stage for adjusting the mask-resist distance. In this way, the position of the mask relative to the resist can be changed while the distance between the substrate 604 and the photoresist 107 remains large. This allows the use of an inexpensive stage and therefore is advantageous.

A parallel blade spring 702 (Fig. 8B) or blade spring 703 (Fig. 8C) made of phosphor bronze or the like may be interposed as a movable portion between the inner substrate 105 and the outer substrate 604 to join the substrates. The spring 702 or 703, or the like that does not have an external driving mechanism may be deformed by utilizing the pressure difference for making the membrane portion 104 sag. The spring 702 or 703 does not have to be as thin as the membrane portion, and therefore may be sagged more than the membrane portion 104 by adjusting the elasticity of the spring.

Embodiment 7

In Embodiment 6, an elastic hinge structure obtained by micromachining employed for the movable portion for splitting the stress in the membrane portion by reducing the membrane mask-resist distance in part. Alternatively, an actuator 701 of Fig. 8A may be employed. The actuator may be of the

electrostatic type, magnetic force type, or piezoelectric type, or may be a linear motor or a piezo mechanism.

In the case of a motor, piezo mechanism, or the like that has an external driving mechanism, the mechanism is driven to reduce the distance between a light exposure pattern 101 on the mask and a photoresist. Then a membrane portion 104 is sagged.

The photomask durability can be improved also by combining the methods shown in the above seven embodiments. In this case, attention needs to be paid so that stress concentrated portions of the methods are positioned in different locations.

For instance, a level difference structure may be formed in a substrate while the level difference structure is provided with a notch structure (Fig. 9A). Another example is to form the level difference structure 401 and then form the elastic hinge structure 601 (Fig. 9B).

As has been described, according to the present invention, a stress relieving structure is given to a photomask for near-field exposure that has a membrane portion. The stress relieving structure relieves stress concentrated locally on the border between the membrane portion and a substrate, and thus the durability of the photomask is improved.